# HCD Online Guidance

# Livestock Grazing on Federal Lands

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**Introduction**

This technical guidance is intended for use by HCD staff in making ESA effects determinations during Section 7 consultations. The guidance is based on the best scientific and commercial data available. This is internal guidance to NOAA staff that provides a default analytical framework for analyzing the effects of livestock grazing on listed anadromous fish on Federal lands. The application of this guidance is not mandatory upon staff nor external customers. This guidance should be considered a "living" document. We expect it will be revised and updated on a periodic basis as we gain experience applying it in a variety of circumstances across the region.

**Background**

Livestock grazing occurs extensively on the National Forests and Bureau of Land Management (BLM) districts throughout the Interior Columbia and Snake River basins. These areas are also home to several stocks of ESA-listed salmon and steelhead. The U.S. Forest Service (USFS) and BLM issue permits for grazing livestock to local ranchers. Each rancher or permittee is authorized to graze a defined number of livestock on a specific area known as an allotment. Allotments are further broken down by fences or geographic features into pastures or units. The USFS and BLM develop allotment management plans (AMPs) to provide long-term management direction (usually 10 years) for the allotment. Annual operating instructions (AOIs) direct the specific management of an allotment for a given year and are issued to permitees annually. This guidance is intended for application to livestock grazing on Federal lands throughout the Pacific Northwest. Management of grazing and ranching operations on private land in this region differs from Federal lands grazing. Livestock tend to be confined in smaller areas, pasture units are normally smaller, and irrigation of pastures often occurs. The effects to listed species from these activities is generally different from the effects of Federal lands grazing and is outside of the scope of this guidance.

*Cows grazing on a Forest Service allotment.*

**PACFISH and Managing Grazing to Protect Anadromous Fish Habitat**

In response to the ESA listings of several salmon and steelhead stocks in the interior basins of the Pacific Northwest, the USFS and BLM issued the Interim Strategy for Managing Anadromous Fish-producing Watersheds in Eastern Oregon and Washington, Idaho, and Portions of California (PACFISH) (USDA and USDI 1995). This interim strategy amended land and resource management plans (National Forests) and resource management plans (BLM Disticts) for areas within the range of listed salmonids but outside of the area covered by the Northwest Forest Plan. PACFISH identified specific riparian management objectives (RMOs) for USFS and BLM managers to use when conducting resource management activities across the landscape. RMOs were defined in PACFISH as “quantifiable measures of stream and stream-side conditions that define good anadromous fish habitat, and serve as indicators against which attainment, or progress toward attainment, of the (riparian) goals will be measured.”

These interim RMOs apply to streams in watersheds with anadromous salmonids. Standards and guidelines established by the PACFISH interim strategy regulate various land management activities including livestock grazing. Standards and guidelines for grazing management direct the USFS and BLM to adjust grazing practices that may retard the attainment of RMOs or have adverse effects on listed anadromous fish. Furthermore, the USFS or BLM is to suspend grazing when modifying practices is not effective in meeting RMOs and avoiding adverse effects on listed anadromous fish (PACFISH Standard and Guideline GM-1, page C-12).

On August 14, 1995, the USFS issued Enclosure B – Recommended Livestock Grazing Guidelines, a supplement to PACFISH. Enclosure B provided further guidance and interpretation of the PACFISH direction specific to livestock grazing and includes programmatic guidelines and management considerations for livestock grazing. This guidance is still in use today on many national forests in the region.

PACFISH’s interim direction provides specific guidance to Federal land managers for managing grazing in riparian areas. Prior to the issuance of PACFISH and as part of their management direction, most national forests and BLM districts had established utilization standards for grazing in riparian areas. These standards are usually based on a percentage of plant tissue removed or “residual herbaceous stubble height.” Forest plans and land and resource management plans normally prescribe seasonal utilization standards at 40 to 50 percent utilization of plant tissue, or two to six inches of residual herbaceous stubble height measured along the greenline[1] of streams. PACFISH did not specifically establish or change current utilization standards, but rather provided guidelines to consider when formulating these standards.

[1]The first continuos band of vegetation found adjacent to a stream’s edge.

**A Review of the Effects of Grazing on Salmonids and their Habitat**

**Direct Effects on Salmonids**

*A trampled steelhead redd.*

Direct effects of livestock grazing may occur when livestock enter the streams occupied by salmon or steelhead to loaf, drink, or cross the stream. During the early phases of their life cycle, juvenile salmonids have little or no capacity for mobility, and large numbers of embryos or young are concentrated in small areas. Livestock entering fish-spawning areas can trample redds, and destroy or dislodge embryos and alevins. Belsky *et al.* (1997) provide a review of these direct influences on stream and riparian areas. Wading in streams by livestock can be assumed to induce mortality on eggs and pre-emergent fry at least equal to that caused by human wading (Roberts and White 1992). In this investigation, a single wading incident on a simulated spawning bed induced 43 percent mortality of pre-hatching embryos. In a recent (July 12, 2000) occurrence of unauthorized livestock grazing in the Sullens Allotment on the Malheur National Forest, five out of five documented steelhead redds in a meadow area of a Rosgen C-type stream channel (Rosgen 1996) in Squaw Creek (Middle Fork John Day River subbasin) were trampled by cattle (U.S. Forest Service memorandum, August 17, 2000).

Direct impacts to salmon and steelhead spawning areas can be avoided by scheduling grazing in pastures containing spawning habitat after emergence of alevins is complete, or by excluding known spawning areas from livestock access. The period during which summer steelhead adults may be susceptible to harassment, or eggs and pre-emergent fry susceptible to trampling by livestock, is generally from March 15 to July 15. Chinook salmon adults are most susceptible to harassment from early August to the end of the grazing season in most areas (mid-October). Eggs and pre-emergent fry of this species are susceptible to trampling by livestock from August to the following spring. In some allotments or pastures, there are pre-existing natural

*Juvenile steelhead.*

topographic, geologic, and vegetative features, or high spring water flows that naturally exclude or minimize livestock use in spawning areas.

Other forms of direct take (*i.e.*, harassment of juvenile or adult salmonids by livestock when livestock enter or are adjacent to occupied habitat, resulting in salmonid behavioral modifications) are more difficult to address. Direct take in the form of harassment can be reduced in the long term by rangeland management that results in better riparian and in-channel habitat conditions and creates more cover and other important habitat features conducive to salmon steelhead survival and recovery.

*Stream channel downcutting caused by historical grazing practices.*

Cattle wading into a stream to loaf, drink, or cross the stream have the potential to frighten juvenile salmonids from streamside cover. Once these juveniles are frightened from cover and swim into open water, they become more susceptible to predation. In most cases, the risk of juvenile salmonids death due to flushing from cover by watering cattle is minimal.

**Indirect Effects to Salmon, Steelhead and their Habitat**

Numerous symposia and publications have documented the detrimental effects of livestock grazing on stream and riparian habitats (Johnson *et al.* 1985; Menke 1977; Meehan and Platts 1978; Cope 1979; American Fisheries Society 1980; Platts 1981; Peek and Dalke 1982; Ohmart and Anderson 1982; Kauffman and Krueger 1984; Clary and Webster 1989; Gresswell *et al.* 1989; Kinch 1989; Chaney *et al.* 1990, Belsky *et al.* 1997). These publications describe a series of synergistic effects that can occur when cattle over-graze or impact riparian areas: (1) Woody and hydric herbaceous vegetation along a stream can be reduced or eliminated; (2) streambanks can collapse due to livestock trampling; (3) without vegetation to slow water velocities, hold the soil, and retain moisture, erosion of streambanks can result; (4) the stream can become wider and shallower, and in some cases downcut; (5) the water table can drop; and (6) hydric, deeply rooted herbaceous vegetation can die out and be replaced by upland species with shallower roots and less ability to bind the soil. The resulting instability in water volume, increased summer water temperature, loss of pools and habitat adjacent and connected to streambanks, and increased substrate fine sediment and cobble-embeddedness adversely affect salmon and steelhead and their habitat. Specific effects on salmon and steelhead habitat elements are described below.

Riparian Vegetation and Shade

In areas under historic season-long grazing, major vegetation changes can and have taken place with changes in livestock use. Routinely grazing an area too late in the growing season can cause adverse changes in the plant community. Individual plants are eliminated by re-grazing them during the growing season and not allowing adequate recovery after grazing. Regardless of seral stage, four to six inches of residual stubble or regrowth is recommended to meet the requirements of plant vigor maintenance, bank protection, and sediment entrapment (Clary and Webster 1989). More than six inches of stubble height may be required for protection of critical fisheries or easily eroded streambanks and riparian ecosystem functions (Clary and Webster 1989). In the Blue Mountains of eastern Oregon, regrowth of herbaceous vegetation does not normally occur after July (Gillen *et al.* 1985). Consequently, any livestock use of riparian vegetation in the summer and fall needs to be closely managed to ensure adequate residual stubble height to protect streambanks during high streamflows in winter and spring.


*Shallow rooted bluegrass and forbs provide little bank stabilization.*

Over time, entire plant communities can change as a result of heavy or prolonged grazing pressure. In mountain riparian systems of the Pacific Northwest, the replacement of native bunch grass with Kentucky bluegrass has occurred in many areas. Kentucky bluegrass is established as a dominant species in many native bunch grass meadows as a result of overgrazing and subsequent habitat deterioration. Plants in the early seral stage community such as Kentucky bluegrass, do not provide as much protection for the watershed and streambanks. Many forbs and annual plants that frequently dominate early seral plant communities do not have the strong deep root systems of the later seral perennials such as bunch grasses, sedges, rushes, shrubs, and willows. Kauffman *et al.* (1983) found that when grazing in moist meadows was halted, succession towards a more mesic/hydric plant community occurred.

Removal of riparian vegetation reduces aquatic habitat quality, resulting in negative impacts on fish production (Platts and Nelson 1989). Reductions in streambank cover provided by overhanging vegetation, vegetation roots, and undercut banks has been correlated to reduced fish production (EPA 1993). These effects are particularly evident in meadow systems, where herbaceous vegetation may provide the only shade to stream channels. Stream cover in hardwood dominated riparian systems can also be damaged, in some situations, by livestock grazing. Shrubby vegetation, such as willows, may be an important source of shade along smaller streams and in mountainous areas (Henjum *et al*. 1994). Cattle often begin to browse woody species when stubble height of palatable herbaceous species falls below 10 cm, or approximately 4 inches (Hall and Bryant 1995). Others suggest that 10 to 20 cm, or approximately 6-8 inches, of herbaceous residual stubble height may be needed to protect hardwoods, especially during late season grazing (Clary and Leininger 2000).

*Willows recovering after a switch to spring grazing.*

In a study of late season grazing in the Blue Mountains of eastern Oregon, Kauffmann *et al.* (1983) found that shrub use was generally light except on willow-dominated gravel bars. They conclude that on gravel bars, succession was retarded by livestock grazing. In a later study in the same area, Green and Kauffman (1995) found livestock disturbance and ecosystem response to be highly variable among plant communities. In areas rested from grazing in this study, abundance of undesirable non-native species decreased. They also found that in grazed areas, height, establishment, and reproduction of woody species on gravel bars was less than in ungrazed areas. These studies suggest that although livestock grazing may not have adverse effects on mature individuals of woody species such as willows, recolonization of disturbed areas, such as gravel bars, may be impeded by livestock grazing. Another study with similar results found that regeneration of some woody vegetation, such as willow, cottonwood, and aspen is inhibited by browsing on seedlings (Fleischner 1994). A study by Shaw and Clary (1996) found that willow height and density were greatest in pastures grazed in spring or ungrazed as compared to pastures grazed season long or grazed in the fall.

Some authors have recommended long term rest (3 to 10+ years) for the recovery of heavily grazed riparian hardwood communities (Elmore and Beschta 1987, Fleischner 1994) Others contend that long term rest is not necessary for hardwood recovery if livestock or wildlife use is closely controlled (Manoukian and Marlow 2002).

In a study of watersheds in the John Day River basin in Oregon, Maloney *et al.* (1999) found that watersheds with less than 75 percent surface shade can exceed stream temperature standards for rainbow trout and chinook salmon. Stream temperatures in all heavily grazed watersheds in this study exceeded standards for salmonids. The authors concluded that revegetation of the streamside area with shrubs or small trees would likely result in reduced stream temperatures and an improved environment for rainbow trout and chinook salmon. They further suggest that the integrity of the riparian zone could be maintained by using buffer strips and more stringent control of animal usage in riparian areas.

Li (1994) noted that solar radiation reaching the channel of an unshaded stream in the John Day River basin was six times greater than that reaching an adjacent, well-shaded stream, and that summer temperatures were 4.5°C warmer in the unshaded tributary. Below the confluence of these two streams, reaches that were unshaded were significantly warmer than shaded reaches both upstream and downstream. A separate comparison of water temperatures at two sites of similar elevation in watersheds of comparable size found temperature differences of 11ºC between shaded and unshaded streams (Li 1994). Warming of streams due to a loss of riparian vegetation is likely widespread in the Interior Columbia Basin, and may be particularly acute because of low summer flows and many cloudless days

Livestock indirectly affect plant species composition in riparian areas by aiding the dispersal and establishment of nonnative species ( via seeds carried on the fur or in the dung of livestock) (Fleischner 1994). The presence of nonnative species, especially invasive and highly competitive weed species such as knapweeds and thistles, can disrupt the natural functions of riparian areas.

<u>Streambank Stability and Channel Morphology</u>

Removal of streambank/riparian vegetation as well as mechanical bank damage reduces the structural stability of the stream channel resulting in negative impacts on fish productivity (EPA 1993, Platts 1991). Several studies have shown that heavy livestock grazing pressure causes significant streambank damage (Kaufman *et al.* 1983, Clary and Kinney 2002, Hackey 1989). Studies in eastern Oregon and northern California implicate livestock as a major cause of channel downcutting (Dietrich *et al*. 1993, Peacock 1994). Other studies indicate that light or moderate grazing pressure did not result in significant streambank damage (Buckhouse *et al.* 1981).

Riparian areas over-grazed by cattle often have reduced salmonid living space caused by stream channel widening and decreased depth (Platts and Nelson 1989, EPA 1993). When riparian areas are over-grazed, a synergistic adverse effect on streambank stability occurs. As stubble height of herbaceous vegetation along streambanks decreases, livestock eating this vegetation must move more frequently to achieve dietary intake needs. Increased movement leads to trailing in riparian areas causing more compaction and bank damage (Clary and Lenninger 2000).

<u>Soils</u>

Livestock grazing influences vegetation by modifying soil characteristics. Hooves compact soils that are damp or porous, inhibiting germination of seeds and reducing root growth (Heady and Child 1994). The degree of soil compaction depends on soil characteristics, including texture, structure, porosity, and moisture content (Platts 1991; Heady and Child 1994), and the movement of animals as directed by the permittee or rider. Generally, soils that are high in organic matter, porous, and composed of a wide range of particle sizes are more easily compacted than other soils. Similarly, moist soils are usually more susceptible to compaction than dry soils, although extremely wet soils may give way and then recover following compression by livestock (Clayton and Kennedy 1985).

Changes in soil infiltration capacity associated with soil compression due to livestock may lead to more rapid surface runoff, lowering moisture content of soil and the ability of plants to germinate or persist (Heady and Child 1994). However, sometimes livestock may break up impervious surface soils, allowing for greater infiltration of water and helping to cover seeds (Savory 1988 *cited in* Heady and Child 1994). Soils in arid and semi-arid lands have a unique microbiotic surface layer or crust of symbiotic mosses, algae, and lichens that covers soil between and among plants. This "cryptogamic crust" plays an important role in hydrology and nutrient cycling and is believed to provide favorable conditions for the germination of vascular plants (Fleischner 1994). The hooves of livestock break up these fragile crusts, and reformation may take decades. Anderson *et al*. (1982) found recovery of cryptogamic crusts took up to 18 years in ungrazed enclosures in Utah. In arid and semi-arid climates, the cryptogamic crust has been shown to increase soil stability and water infiltration (Loope and Gifford 1972; Kleiner and Harper 1977; Rychert *et al*. 1978). Disruption of the cryptogamic crust may thus have long-lasting effects on erosional processes.

If improper management leads to overgrazing, livestock indirectly alter surface soils by removing ground cover and mulch. Livestock can cause soil compaction which in turn affects the response of soils to rainfall. Kinetic energy from falling raindrops erodes soil particles (splash erosion), which may then settle in the soil interstices resulting in a less-pervious surface. Livestock grazing can increase the percentage of exposed soil and break down organic litter, reducing its effectiveness in dissipating the energy of falling rain.

<u>Water Quality</u>

Removal of riparian vegetation from grazing results in increased insolation of streams, leading to cumulative increase in downstream temperatures (Barton *et al.* 1985). This is especially true for high desert watersheds of the intermountain West. (Platts and Nelson 1989). Alteration of stream temperature processes may result from changes in channel morphology. As mentioned above, streams in areas that are improperly grazed are wider and shallower than in ungrazed systems, thus exposing a larger surface area to solar radiation (Bottom *et al*. 1985; Platts 1991). Wide, shallow streams heat more rapidly than narrow, deep streams and may cool more rapidly, increasing the likelihood of anchor ice formation.

Bell (1986) reported the upper lethal temperature for steelhead to be 75.02°F with a preferred temperature range of 50-55° F. The ability of rearing salmonids to tolerate temperature extremes depends to a certain degree on the fish's recent thermal history. However, research indicates that most salmonid species are at risk when temperatures exceed 73-77°F (Spence *et al.* 1996). In addition to the lethal effects of high temperatures, ectothermic salmonids rearing at temperatures near the upper lethal limit experience decreased growth because nearly all consumed food is used for metabolic maintenance (Bjornn and Reiser 1991). Temperatures exceeding the upper lethal limits may be tolerated for brief periods, or fish may seek thermal refugia. Li *et al.* (1991) report that resident rainbow trout in an eastern Oregon stream selected natural and artificially created coldwater areas when temperatures in the main stream channel exceeded 75.2°F, but showed no preference for these areas when temperatures in the main stream channel were less than 68°F. Coldwater refugia, such as springs and groundwater seeps, allow some juvenile salmonids to persist in areas where temperatures in main stream channels exceed their upper lethal limit. However, total salmonid production in stream reaches will decrease if the amount of habitat suitable for the species use decreases as temperatures increase and fish are restricted to coldwater refugia.

Increases in stream temperature due to removal of streamside vegetation have a negative effect on dissolved oxygen (DO) concentrations. As temperatures increase, oxygen solubility in water decreases and DO levels decrease. Salmonids require an approximate DO level of 6 mg/l to survive, and suffer no metabolic impairment when DO levels remain at 8 mg/l (Davis 1975). Phillips and Campbell (1961) determined that DO levels must average greater that 8 mg/l for embryos and alevins to have good survival rates. Silver *et al*. (1963) and Shumway *et al*. (1964) observed that salmonids reared in water with low or intermediate oxygen levels were smaller and had a longer incubation period than those raised in high DO levels. Low DO levels increased the incubation periods for anadromous species, and decreased the size of alevins (Garside 1966; Doudoroff and Warren 1965; Alderdice *et al*. 1958). Some studies have shown that salmonids may be able to withstand periods of DO levels as low as 5 mg/l, but growth, food conversion efficiency, and swimming performance will be adversely affected (Bjornn and Reiser 1995).

Because riparian areas are favored by cattle and sheep, nutrients eaten elsewhere on the range are often deposited in riparian zones or near other attractors, such as salt blocks (Heady and Child 1994). The deposition of nutrients in riparian areas increases the likelihood that nitrogen and phosphorous will enter the stream. Nutrients derived from livestock wastes may be more bioavailable than those bound in organic litter.

<u>Prey Base</u>
The coldwater communities which rearing juvenile salmonids rely on require minimum DO levels between 6 and 8 mg/l (ODEQ 1995). The aquatic invertebrates and other coldwater fish that rearing juvenile steelhead rely on for food require DO levels in this range. As temperatures increase and DO levels drop, these communities shift from salmonids and less tolerant aquatic invertebrates, such as mayflies and stoneflies, to a more coolwater structure dominated by sculpins and tolerant aquatic invertebrates such as chironomids.

Reduction in the riparian canopy increases solar radiation and temperature, and thus stimulates production of periphyton (Lyford and Gregory 1975). In a study of high desert streams, Tait *et al.* (1994) found that less-palatable trout prey dominated the food base in warmwater stream reaches exposed to sunlight. They reported that thick growths of filamentous algae encrusted with epiphytic diatoms were found in reaches with high instances of solar radiation, whereas low amounts of epilithic diatoms and blue-green algae dominated in shaded reaches. Periphyton biomass was significantly correlated with incident solar radiation.

While densities of macroinvertebrates in forested streams typically increase in response to increased periphyton production, the effect of stimulated algal growth in rangeland streams is less clear. Tait *et al*. (1994) found that biomass, but not density, of macroinvertebrates was greater in reaches with greater periphyton biomass. The higher biomass was a consequence of many *Dicosmoecus* larvae, a large-cased caddisfly, that can exploit filamentous algae. Consequently, any potential benefits of increased invertebrate biomass to salmonids may be small, because these larvae are well protected from fish predation by their cases. Tait *et al*. (1994) suggest that these organisms may act as a trophic shunt that prevents energy from being transferred to higher trophic levels. A study by Li *et al.* (1994) in the John Day River basin found that colder streams supported the highest standing crops of trout and had the most favorable trout/invertebrate standing crop ratios, suggesting that colder streams in the basin have a greater trophic efficiency leading to salmonid production.

Rinne (1988) found that aquatic macroinvertebrates populations inhabiting a grazed and ungrazed reach of a New Mexico stream were markedly different. Increased densities and biomasses of more tolerant forms of insects were present in the grazed stretches. The author cautions that the changes in community structure cannot be easily attributable to linear changes in stream habitat due to the absence of pre-treatment data.

Inputs of fine sediment resulting from livestock trampling banks can reduce benthic invertebrate abundance and lead to a shift from aquatic insects to molluscs, which are less palatable to salmonids. Studies have shown that sediment inputs resulting in substrate embeddedness of greater than one-third can result in a decrease in benthic invertebrate abundance and thus a decrease in food available for juvenile salmonids (Waters 1995).

Reducing riparian vegetation can reduce habitat for terrestrial insects, an important food for juvenile salmonids (Platts 1991). Riparian vegetation provides organic material directly to the stream, making up about 50 percent of the stream's nutrient energy supply for the food chain (Cummins 1974 *cited in* Platts 1991). This allochthonous material provides an important food source for aquatic insects that in turn become prey for salmonids. Consequently, removal of riparian vegetation can affect the diet of fish by reducing production of both terrestrial and aquatic insects (Chapman and Demory 1963).

<u>Substrate and Sediment</u>

Damage to streams in the western United States from livestock grazing is largely due to the generation of excess sediment caused by livestock overuse of riparian areas (Waters 1995). Cattle or sheep trampling streambanks and the subsequent erosion adds fine sediments to stream substrates. Mass wasting of sediment occurs along streambanks where livestock walk on overhanging cut banks (Behnke and Zarn 1976; Platts and Raleigh 1984; Fleischner 1994). At great risk are salmonid spawning reaches used by anadromous Pacific salmonids and inland trout (Waters 1995).

Increases in fine sediment lead to greater substrate embeddedness and a decrease in the interstitial spaces between gravel substrate important for salmonid spawning. Increases in substrate embeddedness impair food production as described above, and block refugia for young salmonids (Rinne 1990). A general reduction in the quality of spawning and rearing habitat available occurs in these circumstances. Salmonid survival at early life stages has been directly linked to the amount of surface fines in stream substrates (Spence *et al.* 1996, EPA 1993).

Juvenile salmonids depend on clean substrate for cover, especially for over-winter survival (EPA 1993). Successful salmonid spawning requires clean gravels with low fine sediment content (Spence *et al.* 1996). Well oxygenated water must be able to reach eggs and pre-emergent fry during incubation and emergence. Suffocation of these life stages may occur if redds become covered with fine sediment.

Peak/Base Streamflow

Channel downcutting caused by riparian degradation can lower local water tables and reduce the volume of base flow available in dry seasons and periods of drought (EPA 1993). Riparian vegetation has been linked to the water-holding capacity of streamside aquifers (Platts 1991). As riparian vegetation is removed by livestock grazing and streamside soils are compacted by livestock hooves, the ability of areas to retain water is decreased. Johnson (1992) reviewed studies related to grazing and hydrologic processes and concluded that heavy grazing nearly always decreases infiltration, reduces vegetative biomass, and increases bare soil. Decreased evapotranspiration and infiltration cause increase and hastening of surface runoff, resulting in a more rapid hydrologic response of streams to rainfall. When this occurs, high flows in the spring tend to increase in volume, leading to bank damage and erosion. Summer and fall base flows are decreased, often resulting in flows that are insufficient to provide suitable rearing habitat for juvenile salmonids. If aquifers lose their capacity to hold and slowly deliver water to the stream, differences between peak and base discharge rates increase dramatically (EPA 1993). Some streams that typically flowed perennially may experience periods of no flow in the summer or fall. Li *et al*. (1994) found that streamflow in a heavily grazed eastern Oregon stream became intermittent during the summer, while a nearby, well-vegetated reference stream in a similar-sized watershed had permanent flows. They suggested that the difference in flow regimes was a consequence of diminished interaction between the stream and floodplain with resultant lowering of the water table

Many riparian areas of the allotments on Federal lands are not subject to densities of livestock sufficient to cause this degree of reduction in infiltration rates or change in streamflow regime. Experiments in northeastern Colorado showed reductions in infiltration in heavily grazed plots, but no differences between moderately and lightly grazed plots (Rauzi and Smith 1973). There are, however, meadow systems where livestock tend to congregate that could experience these types of effects if grazing is not closely controlled.

Pool Quality/Quantity

*Deep rooted sedges stabilize streambanks and promote streambank rebuilding.*

Instream pools are important habitat for both juvenile and adult salmonids. Fish abundance is related to the diversity of habitats and number and quality of instream pools (EPA 1993). Rearing juvenile salmonids use slow water habitat found in pools, while adult salmonids make use of the cover and deep water found in pools during spawning migrations. Pools with undercut banks are important rearing areas for juvenile salmonids (Bjornn and Reiser 1991). These areas provide overhead cover and water velocities ideal for both juvenile and migrating adult salmonids. Bank trampling by livestock can destroy undercut banks, thereby reducing hiding cover for fish. Introduction of fine sediments to streams can fill in pools, reducing depth and covering coarse substrates. Reduction in the growth of woody species such as aspen and cottonwood along the stream's edge can lead to reductions in instream wood, thus diminishing the retention of spawning gravels and decreasing the frequency of pool habitats

**Determining Utilization Standards**

Federal land management agencies establish utilization standards for livestock grazing in riparian areas that determine "move triggers" for permittees as well as means to gauge the effects of grazing on RMOs. Typically, herbaceous residual stubble height is used as a standard to measure the utilization of riparian forage. In addition to residual stubble height, shrub utilization and streambank damage measurements are sometimes employed as utilization standards. Grazing permittees are instructed by land management agencies to move livestock when thresholds for utilization standards are approached or reached.

Residual herbaceous stubble height refers to the mean or median leaf blade height of certain species or species groups of plants remaining after grazing. Stubble height measurements for riparian areas are usually measured in a transect along the greenline (the first continuous band of vegetation directly adjacent to the waters' edge) or in the flood prone area. The PACFISH/INFISH Interagency Implementation Team (IIT) monitoring module (IIT 2003) and Turner and Clary (2001) detail methodologies for measuring residual stubble height. The BLM, Challis Resource Area (1999) has prepared a photographic guide to median stubble heights.

When land management agencies formulate residual stubble height standards for units or pastures within a grazing allotment, two primary factors are considered. The first factor is the hydrologic function of the vegetation. Herbaceous vegetation plays an important role in maintaining and building streambanks. Stems of herbaceous vegetation slow stream current velocity during high flow events and facilitate the sediment deposition process essential to the building of streambanks. Roots of herbaceous vegetation stabilize the soil and prevent erosion during high flow events. A study by Clary *et al.* (1996) found that in a simulated channel, residual stubble heights of 0.5 to 6 inches of flexible vegetation supported streambank rebuilding process within a single sediment loading and flushing event. They also found that under multiple loading and flushing events, 8 to 12 inches of residual stubble height entrapped and stabilized significant amounts of sediment.

The second factor considered when determining stubble height standards is the contribution the residual vegetation makes to healthy riparian habitat. Herbaceous vegetation provides many important functions in a riparian ecosystem. Overhanging sedges (*Carex* sp.), and rushes (*Juncus* sp.) provide shade to the stream and hiding cover for fish. In meadow systems with meandering, low gradient stream channels, herbaceous vegetation may be the only shade-providing plants. Overhanging herbaceous vegetation can provide valuable overwintering habitat for juvenile salmonids. The presence of a healthy community of hydric vegetation in headwater wetland areas of watersheds plays an important role in maintaining streamflow. The roots of this vegetation wick moisture into the soil during wet periods in the spring, maintaining a high water table. This water is then released gradually throughout the summer and fall, maintaining adequate streamflow during critical periods for juvenile salmonid growth and survival.

In grazed riparian systems, the availability of herbaceous vegetation discourages livestock from browsing hardwood shrubs. When herbaceous forage is in short supply or has become less palatable due to drying or maturation, livestock can be expected to browse hardwood shrubs in riparian areas (Clary and Lenninger 2000, Hall and Bryant 1995, Skinner 1998). Clary and Leininger (2000), provide guidelines for establishing stubble height standards to avoid livestock browsing on hardwood shrubs. They point out that residual stubble heights necessary to avoid browsing on shrubs depend on many factors, and can vary between 10 and 20 cm (approximately 4 to 8 inches).

Considering these two factors, among others, land management agencies establish residual stubble height utilization standards for each unit or pasture. Stubble height utilization standards for riparian areas are typically set between two and six inches of residual stubble height, with most stubble height recommendations falling within the range of four to six inches (Clary and Webster 1990). Sometimes stubble height measurements are taken on the most palatable species such as Kentucky bluegrass (*Poa pratensis*). Other times, hydric vegetation such as sedges and rushes growing along the greenline of streambank are measured. Where and on which species utilization measurements are taken can result in a great difference in the reported condition of the riparian zone after livestock grazing has concluded for the season.

Skinner (1998) points out that there are generally two distinct areas within riparian zones where stubble height may differ, assuming a certain utilization rate. These are: 1) The tall sedge and rush zone occupying the stream's edge; and 2) drier areas where Kentucky bluegrass and tufted hairgrass (*Deschampsia caespitosa*) are the dominant species. In most cases, stubble height on the more palatable bluegrass and hair grass will decrease more quickly than stubble height of sedges and rushes. This is demonstrated on a photograph on page five of Bryant and Hall (1995), showing Kentucky bluegrass in a riparian area grazed to 0.75 inch where less palatable sedges have been grazed to four inches. The authors conclude that livestock use was too long in this pasture and resulted in unwanted browse on willows. Skinner (1998) recommends measuring stubble height in the transition zone between these two areas and correlating data to the amount of hoof imprint in wet areas and bank damage to monitor impacts to riparian zones. Turner and Clary (2001) also address the problem of trying to establish utilization standards for riparian areas where different strata of vegetation exist. They point out that five cm (approximately two inches) in stands of bluegrass may be appropriate, while 15 cm (approximately 6 inches) may be more appropriate for streamside sedge communities.

*Disturbed streambanks recovering after the area was excluded from livestock use for one season with temporary electric fence.*

Caution should be used when selecting stubble height standards below four inches. Although Hall and Bryant (1995) suggest a stubble height of three inches, they were speaking specifically of taking the measurement in flood prone streamside areas usually dominated by palatable species such as bluegrass. This is supported by observations made by Finck *et al.* (2000), who found that, using a greenline monitoring method on sedges, it was difficult to reach a 7.5 cm (approximately three inches) residual stubble height without grazing the entire riparian zone heavily. They point out that in many riparian zones in their study sites, areas close to streams support higher levels of sedges than grasses and livestock seem to graze the grass species first. Sedges were grazed only after grasses had been heavily used.

In certain circumstances, differential plant drying and maturation between riparian and adjacent drier areas can result in livestock shifting to feeding in riparian areas even when adequate forage is available in drier areas (Clary and Lenninger 2000, Hall and Bryant 1995). Hall and Bryant (1995) conclude that drying of herbaceous forage, particularly Kentucky bluegrass, will cause shifts in preference that may adversely impact riparian areas. This factor is important to consider when formulating “move triggers” or utilization standards for riparian areas.

In addition to residual stubble height, shrub utilization and bank damage estimates are sometimes used as utilization standards or move triggers. Bank damage or bank alteration are particularly valuable as utilization standards when livestock grazing occurs in areas where streambanks are overhanging or composed of easily erodible materials. NOAA Fisheries has required that streambank stability in priority watersheds in the Snake River basin be 90 percent or greater (NOAA Fisheries 1995). Some national forests use a bank damage utilization standard of 10 percent (Malheur National Forest 2003), while others rely on stubble height as the sole utilization standard. Observations and conversations during numerous site visits indicate that estimating streambank stability can be difficult, with the possibility for large variation between observer estimates. Amendments to the IIT range monitoring protocol in 2002 and 2003 (IIT 2003) provide a protocol to measure bank damage. In this protocol, estimates of streambank damage are limited to damage caused by livestock, adding interpretation to the protocol. Cowely (2002) proposed guidelines for establishing allowable levels of streambank alteration.

Estimating browse of riparian shrubs can be difficult and somewhat subjective. Often, disagreements occur over whether browsing of shrubs has been caused by livestock or other ungulates such as deer, elk, or wild horses.

**Minimizing Effects from Livestock Grazing**

With the increased focus on riparian protection, grazing management programs have been put in place to protect and enhance riparian condition. In an effort to avoid the adverse effects that can result from improper livestock grazing, the Forest Service and BLM have made many adjustments to their range program. Numerous riparian areas are now fenced to exclude cattle. Fencing sensitive riparian areas is an effective way of protecting riparian resources, fish habitat and fish populations. Platts (1991) found that in 20 of 21 studies identified, stream and riparian habitats were degraded by livestock grazing, and habitats improved when grazing was prohibited in the riparian zone. Storch (1979) reported that in Oregon, in a reach of Camp Creek passing through grazed areas, game fish (trout) made up 77 percent of the population in a fenced exclosure, but only 24 percent of the population outside the exclosure. Total rest from grazing can be one of the best alternatives for realizing rapid recovery of riparian areas (Leonard *et al*. 1997).

Many authors stress limiting the amount of time livestock spend in riparian areas (Erhart and Hansen 1997, Myers 1989). Left on their own, livestock, especially cattle, spend a disproportionate amount of time in riparian areas (Clary and Webster 1989, Bryant 1979), particularly during periods of warm, dry weather. The amount of time livestock grazing occurs in riparian areas can be reduced by limiting the amount of time livestock spend in a pasture containing riparian areas or controlling the amount of time livestock spend in these riparian areas. Erhart and Hansen (1997) noted that in most grazing operations they evaluated, the operations with healthy riparian areas had grazing periods of 45 days or less. Herding of cattle away from riparian areas, placement of mineral supplements (salting) and development of alternative water sources can be used to decrease the amount of time that livestock spend within riparian area of a given pasture.

Permittees rely on salting, herding, and upland water sources to keep cattle away from unfenced riparian areas. The information available on the effectiveness of these techniques is, for the most part, conflicting. Erhart and Hansen (1997) cited three studies done in Oregon on the effectiveness of upland water sources and mineral supplements on reducing use of stream areas by cattle. In two studies, cattle use of stream areas was reduced by the use of these techniques, while another study demonstrated that these techniques did not significantly alter cattle distribution in riparian areas. Riding and herding livestock away from riparian areas is a commonly used technique on Forest Service allotments. Observations made during site visits and the range tours suggest that this technique works well on some allotments but not as well on others. No specific information or data has been collected to support these observations.

Placing salt or mineral supplements in upland areas is often used to decrease the amount of time livestock spend in riparian areas. McInnis and McIver (2001) found that off-stream water and salt attracted cows to the uplands enough to significantly reduce the development of uncovered and unstable streambanks from nine percent in non-supplemented pastures to three percent in supplemented pastures. Ehrhart and Hansen (1997) provide anecdotal evidence that salt, when used in conjunction with alternate water sources, can help distribute livestock over open range. However, they stress that the mineral supplements must be placed far from streams (greater than 1/4 mile). In contrast, Bryant (1982) and Martin and Ward (1973) found that salt placement away from riparian areas did not significantly alter the amount of time livestock spent in riparian zones. Both studies conclude that use of mineral supplements alone will not influence livestock distribution appreciably. Mosley *et al.* (1997) summarize several studies that reported use of mineral supplements increased livestock use of uplands. They generally conclude, however, that mineral supplements alone are ineffective at overcoming the attraction of water, shade, and palatable vegetation found in riparian areas.

Establishing utilization standards for residual stubble height, shrub use, and bank damage, and moving livestock when these standards are approached or reached, will help to avoid many of the adverse effects that livestock grazing can have on fish and their habitat. Permittees are expected to meet these standards each grazing season and the Federal land management agencies rely on a monitoring plan to ensure compliance with these standards. Leaving four to six inches of residual stubble height will help protect streambanks from erosion during subsequent high flow events. It should also minimize livestock use of riparian shrubs that provide shade to streams. Limiting bank damage should prevent adverse changes to stream channel morphology and width/depth ratios. Damage to streambanks and riparian soils is minimized by delaying livestock turn-out until soils are relatively dry.

Compliance or implementation monitoring is essential to the success of any grazing program (Leonard *et al.* 1997). Most national forests and BLM districts in the Interior Columbia basin rely on the IIT implementation monitoring plan. Monitoring for and responding to instances of unauthorized use of livestock is also important. Leonard *et al.* (1997) point out that it only takes a few weeks of unauthorized use or overgrazing to set back years of progress in improving riparian systems. Many authors have concluded that efforts of operators (permittees) and managers (Forest Service and BLM) are more important than any particular system or approach to meeting objectives for livestock grazing in riparian areas (Ehrhart and Hansen 1997, Chaney *et al.* 1993).

**Evaluating Grazing Strategies**

<u>Season-Long Grazing</u>
Season-long grazing refers to grazing throughout the growing period with little or no effort to control livestock distribution. Many authors conclude that this type of grazing system will result in overgrazing riparian areas (Platts 1991, Leonard *et al.* 1997). As temperatures increase during the summer months, livestock will spend more time in riparian areas, increasing the chance of bank trampling and browse of woody species. This strategy is generally viewed as incompatible with good fisheries habitat and is seldom used on Federal lands grazing allotments.

<u>Winter Grazing</u>
Grazing during the period of plant dormancy and cold temperatures is a strategy employed to reduce impacts on riparian areas. Soils are frozen and compaction and streambank alteration tend to be minimal. From a physiology standpoint, grazing during the dormant season may be the least stressful to herbaceous plants. If draw bottoms or riparian areas are colder than the surrounding uplands, livestock may avoid them. In contrast, during severe weather events livestock may congregate in draw bottoms and riparian areas dominated by woody species and these areas may be damaged if used repeatedly (Erhart and Hansen 1997).

Winter grazing does have possible disadvantages. Winter may be the time of greatest browse of woody species by both livestock and wildlife (Leonard *et al.* 1997, Erhart and Hansen 1997). In some areas winter grazing may result in increased vigor of sedge communities but over-use of riparian shrubs (Elmore and Kauffman 1994). Removing riparian vegetation just prior to spring high flows may leave streambanks unprotected during these events.

In high elevation areas, snow will limit the possibility of winter grazing. On Federal lands, canyon lands and lower elevation areas, typically BLM land, are possible areas for winter grazing.

<u>Spring Grazing</u>
Spring grazing is becoming a more popular strategy to protect the health of riparian areas. Spring grazing has the greatest chance for success when there is sufficient herbaceous forage in uplands, cool temperatures may discourage livestock loitering in riparian areas, soils in riparian areas are wet enough to discourage livestock use, and/or well drained soils reduce the possibility of soil compaction (Erhart and Hansen 1997, Clary and Webster 1989, Kinch 1989).

Many range management specialists believe that livestock spend less time in riparian areas during spring. Two recent studies have found that livestock are not as disproportionately attracted to riparian areas in spring as they are in summer or fall (Clary and Booth 1993, Parsons *et al.* 2003). The presence of abundant herbaceous vegetation in both riparian and upland areas may prevent unwanted browse of riparian woody species such as willows. Spring grazing provides more opportunity for regrowth and plant recovery than summer or fall use (Leonard *et al.* 1997). Clary and Webster (1989) conclude "While no one management approach is best for all situations, spring grazing has shown promise in many areas of the Western United States." Crouse (1987), Elmore (2003), and Leonard *et al.* (1997) give examples of improved riparian conditions after a switch to spring grazing.

Despite its growing popularity, spring grazing does have some possible disadvantages. Soil moisture content in riparian areas and potential for soil compaction may be high. Streambanks are highly susceptible to damage when moisture content is high. Marlow and Pogacnik (1985) found that most bank damage occurred when soil moisture content was in excess of 10 percent. Leonard *et al.* (1997) point out that soil moisture content that minimizes streambank damage may vary with differences in soil texture.

From a fisheries perspective, spring grazing may increase the chance of trampling redds of steelhead or other spring-spawning fishes. The chance of redd trampling generally increases with redd density and amount of time livestock spend in riparian areas. Some stream channel types, such as Rosgen C and E (Rosgen 1996) channels found in meadow areas, seem to have higher probabilities for redd trampling because of flat surrounding topography and the tendency of livestock to congregate in these areas. In other areas, steep topography or high stream flows may limit the probability of livestock coming in contact with redds.

<u>Summer Grazing</u>

Summer or hot season grazing is prevalent across Federal lands throughout the western United States. This is especially true for high elevation areas where range conditions are not suitable for grazing until late June or July. Summer is both the period of greatest photosynthetic activity for plants and is also when grazing causes the most stress to plants (Leonard *et al.* 1997). Livestock tend to spend more time in riparian areas and consume more riparian vegetation in the summer months. Most authors agree that grazing without close control of livestock during the summer is detrimental to riparian areas (Leonard *et al.* 1997, Platts 1991, Erhart and Hansen 1997, Clary and Webster 1989). As upland vegetation begins to dry and become less palatable to livestock, more time is spent in riparian areas consuming succulent vegetation located there. Riparian shrubs become more attractive to livestock as the quality of herbaceous vegetation decreases.

Management techniques such as herding, salting, and development of off-site water can be used to limit the amount of time livestock spend in riparian areas. Additionally, pasture rotation schemes such as deferred rotation or rest rotation can be employed to avoid grazing the same areas every year during the summer months.

Late summer grazing may have adverse effects on summer-spawning fish such as spring/summer chinook salmon. The chance livestock may come into contact with redds may be higher in the summer because livestock tend to spend more time in riparian areas and stream flows are lower.

Fall Grazing

Fall or late season grazing is another widespread strategy used throughout the Federal lands in the western states, especially in high elevation areas. Erhart and Hansen (1997) recommend fall grazing for achieving healthy riparian areas when the plant communities of these areas are dominated by herbaceous and not woody vegetation. This is because consumption of woody species by livestock tends to increase as herbaceous vegetation dries and becomes less palatable during the summer. Soils tend to be drier in fall, so streambank alteration may be reduced. However, heavy utilization in the fall may leave streambank vegetation reduced and banks vulnerable to damage during the next high flow event (Leonard *et al.* 1997).

In many areas, upland vegetation may begin to regrow as temperatures cool and precipitation resumes. Livestock may discontinue loitering in riparian areas to make use of this vegetation. In other areas, livestock may continue to congregate in riparian areas because the only remaining succulent vegetation is found in these areas. As with summer and spring grazing, fall grazing can impact fall spawning fish such as bull trout and fall chinook salmon.

Rest Rotation

In rest rotation grazing systems, one pasture in an allotment is rested every year. The period of rest is rotated among pastures over the complete cycle. Often, three or more pastures are used in this system. The obvious benefit of this system is that riparian areas in at least one pasture are allowed a full growing season to recover each year. The literature reports mixed results for this grazing system when trying to facilitate recovery in riparian areas. Elmore and Kauffman (1994) report degradation of a high gradient stream under this type of system. Leonard *et al.* 1997 report several successes of this system throughout areas in the arid West. Platts (1991) ranks this type of system as having a fair chance or achieving restoration of riparian resources.

It should be noted that the level of utilization in pastures to be grazed in a season will in large part determine the success of this system. The effects of overgrazing will generally not be mitigated by one season of rest every three or four years. Chaney *et al*. (1993) point out that rest rotation systems work well for sedge-rush-grass communities but not as well for willow dominated riparian areas, as livestock can consume three years of willow growth in one summer grazing period.

Deferred Rotation

In deferred rotation grazing systems, one or more pastures are not grazed during part of the year. This deferment is then rotated among the pastures during following years. For instance, an allotment made up of three pastures (A, B, and C) may be grazed in the following manner one year: A-early season, B-summer, and C-fall. In the next year, the allotment may be grazed C-early season, A-summer, and B-fall. This type of grazing system allows a period of rest during the growing season for each pasture every few years. During this rest period, plants can store carbohydrates and put out seed without the pressure of grazing. The number of pastures may be as few as two and more then 30 depending on the size of the allotment or ranch.

Leonard *et al.* (1997) give examples of the success of this system in protecting riparian areas, but stress that livestock must be moved from pasture to pasture quickly for this system to be effective. Platts (1991) rates this system as fair for stream/riparian rehabilitation potential. Utilization of riparian grasses and woody species must be carefully monitored in pastures grazed during summer and fall, as shifts in palatability may lead to increased use of these plants. Streambanks should be left with sufficient cover to withstand high flow events the following spring.

A study in Nevada by Myers and Swanson (1995) found that a switch to deferred grazing strategy result in improved riparian and stream condition. This study also found that complete rest resulted in the greatest degree of recovery and factors like road crossing along streams can complicate efforts to reach restoration goals by switch grazing strategies.

**Conclusion**

Livestock grazing will continue to be a integral component of multiple use management on Federal lands. The information available indicates that grazing, if expertly managed, can be compatible with recovery of listed salmonids and the proper functioning of their habitat processes. It is the role of NOAA Fisheries biologist, along with ESA Level 1 Streamlining Teams, to provide technical assistance to the land management agencies to ensure this is accomplished. NOAA Fisheries biologists may use and share this guidance in performing that role, along with any other scientifically credible information.

**Links**

The **Forest Service Rangelands Homepage** is a good reference for background information on how grazing is administered on National Forest Lands and Federal legislation regarding livestock grazing: http://www.fs.fed.us/rangelands/

**BLM Grazing Information website** provides up-to-date information on regulations for grazing on BLM lands: http://www.blm.gov/grazing/

**PACFISH/INFISH homepage** provides a wealth of information on grazing monitoring throughout the Federal lands of West with ESA-listed fish : http://www.fs.fed.us/rm/boise/teams/fisheries/pac_infish/pac_infishhome.htm

The BLM maintains a **National Riparian Service Team** to provide guidance and advice on Federal lands grazing and riparian management: http://www.or.blm.gov/nrst/index.htm

The **University of Idaho's Rangeland Ecology and Management Department** is one of the larger range management schools in the country: http://www.cnr.uidaho.edu/range/

**References**


Alderice, D. F., W. P. Wickett, and J. R. Brett. 1958. Some effects of temporary exposure to low dissolved oxygen levels on Pacific salmon eggs. Journal Fisheries Research Board of Canada 15:229-250.

American Fisheries Society. 1980. Western Division. Position paper on management and protection of western riparian stream ecosystems. 24 p.

Anderson, D. C., K. T. Harper, and R. C. Holmgran. 1982. Factors influencing development of cryptogamic soil crusts in Utah deserts. Journal of Range Management 35(2): 180-185.

Barton, D.R., W.D. Taylor, and R.M. Biette. 1985. Dimensions of riparian buffer strips required to maintain trout habitat in southern Ontario streams. North American Journal of Fisheries Management. 5:364-378.

Bell, M.C. 1991. Fisheries handbook of Engineering requirements and biological criteria. Fish Passage Development and Evaluation Program. U.S. Army Corps of Engineers. North Pacific Division.

Bell, M.C. 1986. Fisheries handbook of engineering requirements and biological criteria. U.S. Army Corps of Engineers, Office of the Chief of Engineers. Fish Passage Development and Evaluation Program. Portland, Oregon.

Belsky, J., A. Matzke, and S. Uselman. 1997. Survey of livestock influences on stream and riparian ecosystems in the western United States. Oregon Natural Desert Association. 38 p.

Behnke, R. J. and M. Zarn. 1976. Biology and management of threatened and endangered western trouts. General Technical Report RM-28. U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experimental Station, Fort Collins, Colorado.

Bjornn, T.C., and D.W. Reiser. 1991. Habitat requirements of salmonids in streams. Pages 83-138, *In* W.R. Meehan (editor) Influences of forest and rangeland management on salmonid fishes and their habitats. Special Publication 19. American Fisheries Society, Bethesda, Maryland.

Bottom, D. L., K. K. Jones, and M. J. Herring. 1984. Fishes of the Columbia River estuary. Columbia River Estuary Data Development Program. 113 p.

Buckhouse, J.C., J.M. Skovlin, and R.W. Knight. 1981. Streambank erosion and ungulate grazing relationships. Journal of Range Management 34(4). 2p.

Bryant, L.D. 1979. Livetsock response to riparian zone exclusion. M.S. Thesis, University of Idaho. Moscow, Idaho.

Bryant, L.D. 1982. Response of livestock to riparian zone exclusion. Journal of Range Management 35(6). 6p.

Chaney, E., W. Elmore, and W. S. Platts. 1990. Livestock grazing on western riparian areas. Report prepared for U.S. Environmental Protection Agency by Northwest Resource Information Center, Inc., Eagle, Idaho. 45 p.

Chaney, E., W. Elmore, and W.S. Platts. 1993. Managing change: Livestock grazing on western riparian areas. Report prepared for U.S. Environmental Protection Agency by Northwest Resource Information Center, Inc., Eagle, Idaho. 31 p.

Chapman, D.W. and R.L. Demory. 1963. Seasonal changes in the food ingested by aquatic insect larvae and nymphs in two Oregon streams. Ecology. 44: 140-146.

Chilcote, M.W. 1997. Conservation status of steelhead in Oregon. Draft report, dated September 9, 1997, Oregon Department of Fish and Wildlife, Portland, Oregon. 109 p.

Clary, W. P. and B. F. Webster. 1989. Managing grazing of riparian areas in the Intermountain Region. General Technical Report INT-263, U.S. Dept. of Agriculture, USFS, Intermountain Research Station, Ogden, Utah. 11 p.

Clary W.P. and G.D Booth. 1993. Early season utilization of mountain meadow riparian pastures. Journal of Range Management. 46(6): 493-497.

Clary, W.P and C. I. Thorton. and S.R. Abt. 1996. Riparian stubble height and recovery of degraded streambanks. Rangelands. 18(4). 4p.

Clary, W.P and W.C. Leininger. 2000. Stubble height as a tool for management of riparian areas.
Journal of Range Management. 53 (6): 563-573.

Clary, W.P. and J.W. Kinney. Streambank and vegetation response to simulated cattle grazing. Wetlands 22(1): 139-148.

Clayton. J. L., and D. A. Kennedy. 1985. Nutrient losses from timber harvest on the Idaho Batholith. Soil Science Society of America Journal 49:1041-1049.

Cope, O. B. (ed.). 1979. Proceedings of the forum - grazing and riparian/stream ecosystems. Trout Unlimited. 94 p.

Cowley E.R. 2002. Guidelines for establishing allowable levels of streambank alteration. Bureau of Land Management, Idaho State Office. March. 12 p.

Crouse, M.R. 1987. New approaches to riparian area management on public lands. *In:* Wetland and Riparian Ecosystems of the American West. Proceedings of the Society of Western Scientists' Eighth Annual Meeting. May 26-29, Seattle, Washington. P 32-35.

Cummins, K.W. and G.L. Spangler. 1978. Stream ecosystems. Water Spectrum. 10:1-9.

Davis, J.C. 1975. Minimal dissolved oxygen requirements of aquatic life with emphasis on Canadien species: a review. Journal of Fisheries Research Board of Canada 32:2295-2332.

Dietrich. W. E., C. J. Wilson. D. R. Montgomery, and J. McKean. 1993. Analysis of erosion thresholds, channel networks and landscape morphology using a digital terrain model. Journal of Geology 101:259-278.

Dourdoroff, P., and C. E. Warren. 1965. Environmental requirements of fishes and wildlife: dissolved oxygen requirements of fishes. Special Report141. Oregon State University, Agricultural Experiment Station, Corvallis Oregon.

Ehrhart, R.C. and P.L. Hansen. 1997. Effective cattle management in riparian zones: a field survey and literature review. USDI, Bureau of Land Management, Montana State Office. November.

Elmore, W. 2003. Presentation on recovery of Bear Creek given at Rangelands and Rainbows Conference. Society for Range Management and American Fisheries Society. April 29-30 Prineville, Oregon.

Elmore, W. and R.L. Beschta. 1987. Riparian areas: perceptions in management. Rangelands 9: 260-265.

Elmore, W. and B. Kauffman. 1994. Riparian and watershed systems: Degradation and Restoration. *In*: Ecological Implications of Livestock Herbivory in the West. Society for Range Management, Denver, Colorado. 297 p.

EPA (United States Environmental Protection Agency). 1993. Monitoring protocols to evaluate water quality effects of grazing management on western rangeland streams. Region 10, Seattle, WA. 179 p.

Finck, R., C. Marlow, and J. Borkowoski. 2000. Stubble height as a criteria for water quality. International Conference on Riparian Ecology and Management in Multi-land Use Watersheds. August. 5p.

Fleischner, T. L. 1994. Ecological costs of livestock grazing in Western North America. Conservation Biology 8:629-644.

Garside, E. T. 1966. Effects of oxygen in relation to temperature on the development of embryos of brook and rainbow trout. Journal Fisheries Research Board of Canada 23:1121-1134.

Gillen, R.L., W.C. Krueger, and R.F. Miller. 1985. Cattle use of riparian meadows in the Blue Mountains of Northeastern Oregon. Journal of Range Management 38(3): 205-209.

Green, D.M. And J.B. Kauffman. 1995. Succession and livestock grazing in a northeast Oregon riparian ecosystem. Journal of Range Management 48(4): 307-313.

Gresswell, R. E., B. A. Barton, and J. L. Kershner (eds.). 1989. Practical approaches to riparian resource management: an educational workshop. May 8 -11, 1989, Billings, Montana. USDI Bureau of Land Management: BLM-MT-PT-89-001-4351. 193 p.

Hackey, P.A. 1989. Riparian vegetation, streambank stability, an land use in the salmon river drainage, Idaho. *In*: Practical approaches to riparian resource management: an educational workshop. May 8 -11, 1989, Billings, Montana. USDI Bureau of Land Management: BLM-MT-PT-89-001-4351. 193 p.

Hall, C.H. and L. Bryant. 1995. Herbaceous stubble height as a warning sign of impending cattle grazing damage to riparian areas. USDA Forest Service General Technical Report PNW-GTR-362. 10 p.

Heady, H. F., and R. D. Child. 1994. Rangeland ecology and management. Westview Press, Inc., Boulder, Colorado.

Henjum, M. G., J. R. Karr, D. L. Bottom, D. A. Perry, J. C. Bednarz, S. G. Wright, S. A. Beckwitt, and E. Beckwitt. 1994. Interim protection for late-successional forests, fisheries, and watersheds: national forests east of the Cascade Crest, Oregon, and Washington. The Wildlife Society, Bethesda, Maryland.

Interagency Implementation Team (IIT). 2003. Implementation monitoring program for PACFISH/INFISH and the 1998 biological opinions for salmon, steelhead, and bull trout: Program manual. July. (Available @ http://www.fs.fed.us/rm/boise/teams/fisheries/pac_infish/pac_infishhome.htm)

Johnson, K. L. 1992. Management for water quality on rangelands through best management practices: the Idaho approach. Pages 415-441 *In* R. J. Naiman, editor. Watershed management: balancing sustainability and environmental change. Springer-Verlag, New York.

Johnson, R. R., C. D. Ziebell, D. R. Patton, P. F. Folliet, and R. H. Hamre (Tech. Coordinators). 1985. Riparian ecosystem and their management: reconciling conflicting uses; first North America riparian conference; April 16-18. Tucson, Arizona. USDA Forest Service Gen. Tech. Rpt. Rm-120. 523 p.

Kauffman, J.B., W.C. Krueger, and M. Vara. 1983. Effects of late season cattle grazing on riparian plant communities. Journal of Range Management 36(6): 685-691.

Kauffman, J. B. and W. C. Krueger. 1984. Livestock impacts on riparian ecosystems and streamside management implications - a review. Journal of Range Management 37(5):430-438.

Kinch, G. 1989. Riparian area management: grazing management in riparian areas. U.S. Bureau of Land Management, Denver, Colorado. Tech. Ref. 737-4. 44 p.

Kleiner, E. F., and K. T. Harper. 1977. Soil properties in relation to cryptogamic groundcover in Canyonlands National Park. Journal of Range Management 30:202-205.

Leonard, S., G. Kinch, V. Elsbernd, M. Borman, and S. Swanson. 1997. Riparian area management. TR 1737 14. Grazing management for riparian wetland areas. USDI Bureau of Land Management and USDA Forest Service. 63 p.

Li, H.W., T.N. Pearsons, C. K. Tait, J. L. Li, and R. Gaither. 1991. Approaches to evaluate habitat improvement programs in streams of the John Day basin. Completion Report. Oregon Cooperative Fishery Research Unit. Department of Fisheries and Wildlife. Oregon State University, Corvallis, Oregon.

Li, H.W. G.A. Lamberti, T.N. Pearsons, C.K. Tait, and J.L. Li. 1994. Cumulative effects of riparian disturbances along high desert trout streams of the John Day Basin, Oregon. Transactions of the American Fisheries Society. 123:629-640.

Loope. W. L., and G. F. Gifford. 1972. Influence of a soil microfloral crust on select properties of soils under pinyon-juniper in southeastern Utah. Journal of Soil and Water Conservation 27:164-167.

Lyford, J.H. Jr. and S.V. Gregory. The dynamics and structure of periphyton communities in three Cascade Mountain streams. Congress in Canada 1974 19(3).

Malheur National Forest. 2003. Biological Assessment for 2003 Livestock Grazing. John Day, Oregon.

Maloney, S.B., A.R. Tiedemann, D.A. Higgins, T.M. Quigley, and D.B. Marx. 1999. Influence of stream characteristics and grazing intensity on stream temperature in eastern Oregon. USDA Forest Service General Technical Report PNW-GTR-459. 19 p.

Manoukian, M. and C.B. Marlow. 2002. Historical trends in willow cover along streams in a southwestern Montana cattle allotment. Northwest Science 76(3):213-220.

Marlow, C.B. and T.M. Pogacnik. 1985, Time of grazing and cattle-induced damage to streambanks. *In*: Riparian Ecosystems and their Management: Reconciling conflicting uses. USDA Forest Service General Technical Report RM-120.

Martin, S.C. and D.E. Ward. 1973. Salt and meal-salt help distribute cattle use on a semidesert range. Journal of Range Management 26(2). 4p.

McInnis, M.L. and J. McIver. 2001. Influence of off-stream supplements on streambanks of riparian pastures. Journal of Range Management 54(4). 4p.

Meehan, W. R. and W. S. Platts. 1978. Livestock grazing and the aquatic environment. Journal of Soil and Water Conservation November - December 1978:274-278.

Menke, J. (ed.). 1977. Symposium on livestock interactions with wildlife, fish and the environment. Sparks, Nevada. USDA Forest Service Pacific Southwest Forest and Range Experiment Station. Berkeley, California.

Mosley, J.C., P.S. Cook, A.J. Griffis, and J. O'Laughlin. 1997. Guidelines for managing cattle grazing in riparian areas to protect water quality: Review of research and best management practices. Idaho Forest, Wildlife, and Range Policy Analysis Group. Report No. 15. University of Idaho. Moscow, Idaho. 67 p.

Myers, L. 1989. Grazing and riparian management in southwestern Montana. Proceedings, Practical Approaches to Riparian Resource Management an Educational Workshop. Billings, Montana.

Myers, T.J. 1995. Impact of deferred rotation grazing on stream channel characteristics in central Nevada: a case study. North American Journal of Fisheries Management 15: 428-439.

NOAA Fisheries. 1995. Biological opinion on land and resource management plans for the Boise, Challis, Nez Perce, Payette, Salmon, Sawtooth, Umatilla, and Wallowa-Whitman National Forests. Portland, Oregon. March. 103 p.

Ohmart, R. D. and B. W. Anderson. 1982. North American desert riparian ecosystems. P. 433-466. *In*: G. L. Bender, ed., Reference Handbook on the Deserts of North America. Greenwood Press, Westport, Connecticut.

Oregon Department of Environmental Quality (ODEQ). 1995. 1992-1994 water quality standards review. Standards and Assessment Section, ODEQ, Portland, Oregon.

Parsons C.T., P.A. Momont, T. Delcurto, M. Mcinnis, and M.L. Porath. 2003. Cattle distribution patterns and vegetation use in mountain riparian areas. Journal of Range Management. 56(4) 334-341.

Peacock, K. A. 1994. Valley fill and channel incision in Meyer's Canyon, north central Oregon. M.S. thesis. Oregon State University, Corvallis.

Peek, J. M. and P. D. Dalke. 1982. Wildlife - livestock relationships symposium; Proceedings 10. (ed). April 20-22, 1982, Coeur d'Alene, Idaho. Univ. of Idaho Forest, Wildlife, and Range Experiment Station. Moscow, Idaho.

Philips, R.W., and H. J. Campbell. 1961. The embryonic survival of coho salmon and steelhead trout as influenced by some environmental conditions on gravel beds. 14th annual report of the Pacific Marine Fisheries Commission, Portland Oregon.

Platts, W. S. 1981. Influence of forest and rangeland management on anadromous fish habitat in western North America -effects of livestock grazing. USDA Forest Service Gen. tech. Report PNW-124. 25 p.

Platts, W. S. 1991. Livestock grazing. pp. 389-424 in Meehan, ed., Influences of Forest and Rangeland Management on Salmonid Fishes and Their Habitats. American Fisheries Soc., Bethesda, Maryland. 751 p.

Platts, W.S., and R.L. Nelson. 1989. Stream canopy and its relationship to salmonid biomass in the intermountain west. North American Journal of Fisheries Management. 9:446-457.

Platts, W. S., and R. F. Raleigh. 1984. Impacts of grazing on wetlands and riparian habitat. Pages 1105-1117 *In* Developing strategies for rangeland management. National Research Council/National Academy of Sciences, Westview Press, Boulder, Colorado.

Rauzi, F., and F. M. Smith. 1973. Infiltration rates: three soils with three grazing levels in northeastern Colorado. Journal of Range Management, 26(2): 126-129.

Rinne, J.N. 1990. The utility of stream habitat and biota for identifying potential conflicting forest land use: Montane riparian areas. Forest Ecology and Management, 33/34: 363-383.

Roberts, B.C., and R.G. White. 1992. Effects of angler wading on survival of trout eggs and pre-emergent fry. North American Journal of Fisheries Management. 12:450-459.

Rosgen, D. 1996. Applied River Morphology. Wildland Hydrology. Pagosa Springs, Colorado.

Rychert, R. C., J. Skunins, D. Sorensen, and D. Porcella. 1978. Nitrogen fixation by lichens and free-living microorganisms in deserts. Pages 20-30 *In* N. E. West and J. Skujins, editors. Nitrogen in desert ecosystems. Dowden, Hutchinson, and Ross, Inc., Stroudsburg, Pennsylvania.

Shaw, N.L. and W.P. Clary. 1996. Willow establishment in relation to cattle grazing on an eastern Oregon stream. *In*: Desired future conditions for Southwestern Riparian Ecosystems: Bringing Interests and Concerns Together. Rocky Mountain Forest and Range Experimental Station General Technical Report RM GTR-272. 148-153.

Shumway, D. L., C. E. Warren, and P. Doudoroff. 1964. Influence of oxygen concentration and water movement on the growth of steelhead trout and coho salmon embryos. Transactions of the American Fisheries Society 92: 342-356.

Silver, S. J., C. E. Warren, and P. Doudoroff. 1963. Dissolved oxygen requirements of developing steelhead trout and chinook salmon embryos at different water velocities. Transactions of the American Fisheries Society 92: 327-343.

Skinner, Q.D. 1998. Stubble height and function of riparian communities. *In:* Stubble Height and Utilization Measurements: Uses and Misuses. Agricultural Experiment Station, Oregon State University. Station Bulletin 682. 72 p.

Spence, B.C., G.A. Lomnicky, RM. Hughes, and R.P. Novitzki. 1996. An ecosystem approach to salmonid conservation. NOAA Fisheries, Environmental and Technical Services Division, Habitat Conservation Branch, 525 NE Oregon Street, Portland, Oregon. 28 p. (Available @ www.nwr.noaa.gov under Habitat Conservation Division, Habitat Guidance Documents)

Storch, R.L. 1979 Livestock-streamside management programs in eastern Oregon. *In*: Proceedings, grazing and riparian-stream ecosystem forum. Trout Unlimited, Vienna, Virginia 56-59.

Tait, C.K., J.L., Li, G.A. Lamberti, T.N. Pearson, and H.W. Li. 1994. Relationships between riparian cover and community structure of high desert streams. Journal of North American Benthological Society 13:45-56.

Turner, D.L, and W.P. Clary. 2001. Sequential sampling protocol for monitoring psature utilization using stubble height criteria. Journal of Range Management. 54(2): 132-137.

U.S. Bureau of Land Management (BLM). 1999. Photographic guide to median stubble heights. Technical Bulletin No. 99-01. Salmon, ID. 23 p.

U.S. Department of Agriculture (USDA) and U.S. Department of Interior (USDI). 1994. Environmental Assessment for the Implementation of Interim Strategies for Managing

Anadromous Fish-producing Watersheds in Eastern Oregon and Washington, Idaho, and Portions of California (PACFISH). March.

U.S. Forest Service. 2000. Report to NOAA Fisheries on Sullens Allotment. Malheur National Forest. Prairie City Ranger District. Memorandum. August 17.

Waters, Thomas. 1995. Sediment in streams: sources, biological effects and control. American Fisheries Society Monograph 7.